ZENER DIODE WITH REDUCED SUBSTRATE CURRENT

TECHNICAL FIELD

[0001] Embodiments of the subject matter described herein relate generally to semiconductor devices. More particularly, the subject matter relates to isolated Zener diodes.

BACKGROUND

[0002] Zener diodes are some of the most extensively-used components in semiconductor technology, and they are used for a wide variety of applications, including voltage regulation and protection from electrostatic discharge events. Two different kinds of current may affect the operation of a Zener diode at breakdown: impact ionization (or avalanche breakdown) current; and tunneling (or Zener breakdown) current. The term "Zener diode" as it is classically used, and as it will be used herein, refers to a diode in which tunneling breakdown and avalanche breakdown occur simultaneously.

[0003] In power integrated circuit (IC) technology, the Zener diode is commonly integrated into a circuit and is in "discrete" form as a separate unit. In general, Zener diodes, especially when used in smart power technologies, should have both zero temperature coefficient ("zero TC") and long term stability. Zero temperature coefficient means that the reverse breakdown voltage is substantially invariant with temperature, within a useful temperature range. Long term stability means that the reverse breakdown voltage and reverse leakage current do not change with time over the useful life of the device. Due to the zero TC and long term stability of Zener diodes, they are widely used in voltage clamping and reference. However, conventional Zener diodes suffer from substrate current injection when forward biased and when reverse biased. This substrate current injection may result in design difficulty because substrate current results in a differential between the anode terminal current and the cathode terminal current. More importantly, a high substrate current injected from the Zener diode(s) may also disturb operation of other devices that share the same semiconductor substrate as the Zener diode(s).

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A more complete understanding of the subject matter may be derived by referring to the detailed description and claims when considered in conjunction with the following figures, wherein like reference numbers refer to similar elements throughout the figures.

[0005] FIG. **1** is a top phantom view of a semiconductor-based vertical Zener diode device configured in accordance with an embodiment of the invention;

[0006] FIG. **2** is a perspective cross sectional view of a portion of the vertical Zener diode, as generally defined by the line **2-2** shown in FIG. **1**;

[0007] FIG. **3** is a cross sectional view of the vertical Zener diode, as viewed along line **3-3** shown in FIG. **1**;

[0008] FIG. **4** is a cross sectional view of the vertical Zener diode, as viewed along line **4-4** shown in FIG. **1**;

[0009] FIG. **5** is a top phantom view of a semiconductor-based lateral Zener diode configured in accordance with an embodiment of the invention; and

[0010] FIG. **6** is a cross sectional view of the lateral Zener diode, as viewed along line **6-6** shown in FIG. **5**.

DETAILED DESCRIPTION

[0011] The following detailed description is merely illustrative in nature and is not intended to limit the embodiments of the subject matter or the application and uses of such embodiments. As used herein, the word "exemplary" means "serving as an example, instance, or illustration." Any implementation described herein as exemplary is not necessarily to be construed as preferred or advantageous over other implementations. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0012] Certain terminology may be used in the following description for the purpose of reference only, and thus are not intended to be limiting. For example, terms such as "upper", "lower", "above", and "below" may refer to directions in the drawings to which reference is made. Other terms such as "front", "back", "rear", "side", "outboard", and "inboard" may be used to describe the orientation and/or location of elements within a consistent but arbitrary frame of reference which is made clear by reference to the text and the associated drawings describing the element under discussion. Such terminology may include the words specifically mentioned above, derivatives thereof, and words of similar import. Similarly, the terms "first", "second" and other such numerical terms referring to structures do not imply a sequence or order unless clearly indicated by the context.

[0013] The terms "inboard" and "outboard" as used herein relate to position relative to a central axis of symmetry or other point, line or plane of reference. Thus, "inboard" means closer to the reference than another component, while "outboard" means further from the reference than another component. In this regard, an outboard feature, element, or region could completely (or partially) surround an inboard feature, element, or region. Moreover, an inboard feature, element, or region could be flanked by one or more outboard features, elements, or regions. Unless otherwise indicated, the frame of reference in this disclosure is a center line or plane of symmetry.

[0014] Zener diodes and their operating principles are well known. A Zener diode allows current to flow in the forward direction (similar to normal diodes), and it also allows current to flow in the reverse direction if the applied voltage is greater than the reverse breakdown voltage. This breakdown voltage is sometimes referred to as the "Zener knee voltage" or simply the "Zener voltage." Zener diodes can be fabricated as semiconductor devices using known semiconductor manufacturing techniques, technologies, and processes. Accordingly, for the sake of brevity, conventional techniques and aspects of semiconductor devices, Zener diode design, and semiconductor device fabrication need not be described in detail herein.

[0015] Zener diodes are commonly realized using either a lateral device structure or a vertical device structure. In a lateral Zener diode, the reverse breakdown current primarily occurs at or near the surface of the device structure; in a vertical Zener diode, the reverse breakdown current primarily occurs deeper below the surface. In either case, conventional Zener diodes exhibit undesirably high substrate current at and beyond the reverse breakdown point. In practice, a high amount of electrons is injected into the cathode region of a